PB87-152088

# Generalized Particle Size Distributions for Use in Preparing Size Specific Particulate Emission Inventories

PEI Associates, Inc., Golden, CO

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Jul 86

U.S. Department of Commerce
National Technical Information Service
NTIS

PB87-152088

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/4-86-013
July 1986

Air

EPA

# Generalized Particle Size Distributions For Use In Preparing Size Specific Particulate Emission Inventories

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA. 22161

## TECHNICAL REPORT DATA

*(Please read Instructions on the reverse before completing)*

| 1. REPORT NO. | 2. | 3. RECIPIENT'S ACCESSION NO. |
|---|---|---|
| EPA-450/4-86-013 | | PB87 152088/AS |

| 4. TITLE AND SUBTITLE | 5. REPORT DATE |
|---|---|
| Generalized Particle Size Distributions For Use In Preparing Size Specific Particulate Emission Inventories | July 1986 |
| | 6. PERFORMING ORGANIZATION CODE |

| 7. AUTHOR(S) | 8. PERFORMING ORGANIZATION REPORT NO. |
|---|---|
| PEI Associates, Inc.<br>Golden, CO 80401 | |

| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | 10. PROGRAM ELEMENT NO. |
|---|---|
| | 11. CONTRACT/GRANT NO.<br>68-02-3512 |

| 12. SPONSORING AGENCY NAME AND ADDRESS | 13. TYPE OF REPORT AND PERIOD COVERED |
|---|---|
| Air Management Technology Branch<br>Monitoring And Data Analysis Division<br>Office Of Air Quality Planning And Standards<br>Research Triangle, NC 27711 | 14. SPONSORING AGENCY CODE |

15. SUPPLEMENTARY NOTES

EPA Project Officer: A. A. MacQueen

16. ABSTRACT

This accumulation of particle size data is intended to be of use to State and local air pollution control agencies in the development of emission inventories. In light of a proposed National Ambient Air Quality Standard for particulate, this document is expected to be of help in the ensuing work on State Implementation Plans.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Emission Inventories<br>Particle Size Data<br>State Implementation Plans<br>Particle Size Distribution | | |

| 18. DISTRIBUTION STATEMENT | 19. SECURITY CLASS *(This Report)* | 21. NO. OF PAGES |
|---|---|---|
| | | 60 |
| | 20. SECURITY CLASS *(This page)* | 22. PRICE |
| | | |

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

EPA-450/4-86-013

# Generalized Particle Size Distribution For Use In Preparing Size Specific Particulate Emission Inventories

By

Keith D. Rosbury
PEI Associates, Inc.
Golden, Colorado 80401

EPA Contract No. 68-02-3512

EPA Project Officer: Arch MacQueen
Air Management Technology Branch
Monitoring and Data Analysis Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

July 1986

This report has been reviewed by the Office Of Air Quality Planning And Standards, U.S. Environmental Protection Agency, and approved for publication as received from the contractor. Approval does not signify that the contents necessarily reflect the views and policies of the Agency, neither does mention of trade names or commercial products constitute endorsement or recommendation for use.

CONTENTS


| | Page |
|---|---|
| Contents | ii |
| Figures and Tables | iii |
| 1. Rationale for Developing Generalized Particle Size Distributions | 1 |
| 2. Basic Approach | 2 |
| 2.1 Basis for Generalized Categories | 2 |
| 2.2 Theoretical or Measured Data | 4 |
| 2.3 Reconciling Differences in the Data Base | 4 |
| 2.4 Control Devices | 5 |
| 3. Development of Generalized Particle Size Distributions for Uncontrolled Sources | 6 |
| 3.1 Identification of References | 6 |
| 3.2 Variations in Data | 7 |
| 3.3 Compilation of Data into Computerized Data File | 14 |
| 3.4 Development of Initial Classification System | 15 |
| 3.5 Development of Final Generalized Categories and Corresponding Size Distributions | 16 |
| 4. Development of Generalized Particle Size Distributions for Controlled Sources | 23 |
| 4.1 Calculation of the Size Distribution for a Controlled Source | 23 |
| 5. How to Use the Generalized Particle Size Distributions and Control Efficiency Data | 25 |
| 5.1 Uncontrolled Sources | 25 |
| 5.2 Controlled Sources | 25 |
| 5.3 Example Calculations | 26 |
| References | 28 |
| Appendix A Generalized Particle Size Distributions | A-1 |
| Appendix B Calculation Sheet | B-1 |

## FIGURES


| Number | | Page |
|---|---|---|
| 5-1 | Example Calculation for Determining Uncontrolled and Controlled Particle Size-Specific Emissions | 27 |


## TABLES


| | | |
|---|---|---|
| 3-1 | Particle Size Category by AP-42 Section | 20 |
| 3-2 | Final Generalized Particle Size Distribution Categories | 22 |
| 4-1 | Average Collection Efficiencies of Various Particulate Control Devices | 24 |

# SECTION 1

## RATIONALE FOR DEVELOPING GENERALIZED PARTICLE SIZE DISTRIBUTIONS

A size-specific National Ambient Air Quality Standard for particulate is being proposed. Implementation of this standard will necessitate the preparation of particle size-specific emission inventories. The U.S. Environmental Protection Agency (EPA) has developed particle size-specific data for a limited number of the processes that account for a large fraction of total national emissions. These data are being incorporated into the Compilation of Air pollutant Emission Factors (AP-42). Still needed, however, is particle size information for many processes that will be of local impact and concern. The purpose of this assignment is to develop generalized particle size distributions applicable to sources that have not been sampled adequately to calculate a size distribution. Generalized size distributions should only be used in the absence of source-specific particle size distributions such as those found in the main text of AP-42. Further, the data should be used for regional emission inventories only, and should not be used for individual source compliance purposes.

# SECTION 2

# BASIC APPROACH

Several technical questions arose at the outset of this attempt to develop generalized particle size distributions. These questions and the report sections in which they are addressed are as follows:

1. On what basis should the generalized categories be created? (Section 2.1)

2. Should the generalized distributions be based on theoretical data, measured data, or some combination? (Section 2.2)

3. If the generalized distributions are based on measured data, how can data measured by various sampling methodologies and instrumentation be reconciled into one data base? (Section 2.3)

4. How should the compounding influence of changes in particle size distribution caused by control devices be treated? (Section 2.4)

## 2.1 BASIS FOR GENERALIZED CATEGORIES

Particle size distribution can be categorized in two different ways:

1. By the basic physical processes generating the emissions (e.g., combustion, melting, grinding, wind erosion).

2. By industry (e.g., metallurgical, mineral products, iron and steel, phosphate fertilizers).

Designing the category system according to the basic physical processes generating the emission was believed to be the more logical approach. Examination of the measured data, however, indicated the need for adding a second dimension, i.e., the material being processed. For example, the emissions generated by the handling of a fine powdery material differ from those generated by the handling of a coarse aggregate.

Designing a category system according to basic industry was found to be infeasible because the emission distributions generated by the many diverse processes within each industry are so dissimilar. For example, the iron and steel industry includes the following basic operations: coke production; sinter production; iron production; steel production; semifinished product preparation; heat and electricity preparation; and handling, transport, and storage of raw materials. Further complicating this approach are the different processes, equipment, and materials used within each of these operations. Because accounting for these differences would necessitate reverting to the basic process/material handled approach discussed in the preceding paragraph, categorization of particle size distribution by industry holds no advantage.

The development of generalized particle size distributions by basic physical process and materials handled is described in Section 3.

## 2.2 THEORETICAL OR MEASURED DATA

A literature search was made of many chemistry, physics, and engineering sources for theoretical approaches to the prediction of particle size distribution. In addition, telephone interviews were conducted with several individuals who are well known for their contributions in the field of particulate technology. Results were very limited. This absence of viable theoretical approaches made it mandatory to rely primarily on measured data.

## 2.3 RECONCILING DIFFERENCES IN THE DATA BASE

During compilation of the data base, more than 400 test series were examined. The data produced by these tests vary widely with respect to their quality because of such factors as number of tests, source operating conditions during the test (percent capacity, representativeness, upset conditions, etc.), test instrumentation (Anderson, Brinks, etc.), quality assurance, method of calculation, physical/aerodynamic/Stokes diameter questions, etc.

The problems created by these diversities were not completely overcome. In the basic reference used, the Fine Particulate Emission Inventory System (FPEIS), the information for each test series was often not available to answer the questions. Documentation in the original reports on which this information was taken is often inadequate. Also, the sheer size of the data set prohibited an in-depth investigation into each test series within the scope of this study.

A procedure for reconciling differences in the data base is discussed in Section 3.

## 2.4 CONTROL DEVICES

The preceding discussion has centered on the particle size distribution of an uncontrolled source. Control devices also influence particle size distributions because each device has a different control efficiency for different particle size ranges. For example, a cyclone has a collection efficiency of about 30 percent for 1.0-μm particles and about 93 to 98 percent for particles in the 20- to 44-μm size range. Also, the same basic process/material can be controlled by different control devices in different applications. Therefore, the number of process/material/control type permutations becomes enormous.

To overcome these two problems, the data for uncontrolled sources were analyzed separately from those from controlled sources. The impact of the control device on the particle size distribution was determined by applying control-device-specific average collection efficiencies by particle size range to an uncontrolled particle size distribution. Table A-2 (taken from AP-42) provides the basis for this approach. These data were updated by using the 1982 EPA publication, Control Techniques for Particulate Emissions from Stationary Sources.

The procedure for accounting for the influence of control devices on particle size distribution is described in detail in Section 5.

## SECTION 3

## DEVELOPMENT OF GENERALIZED PARTICLE SIZE DISTRIBUTIONS FOR UNCONTROLLED SOURCES

The approach decided upon was to develop generalized particle size distributions for uncontrolled sources with measured data according to the basic process and material being handled. This involved the following steps:

(1) Identification of references containing the results of source testing that produced measured particle size distributions.

(2) Development of a procedure to account for variations in the data resulting from differences in sampling methodology, instrumentation, etc.

(3) Compilation of the data base into a computerized data file.

(4) Development of initial generalized particle size classification system.

(5) Development of final generalized particle-size-distribution categories and a size distribution for each category.

(6) Assignment of a generalized particle size distribution to all particulate sources listed in AP-42 that did not already show a particle size distribution.

### 3.1 IDENTIFICATION OF REFERENCES

The EPA has sponsored several studies for the compilation of particle size data. Among these are:

(1) Fine Particle Emission Inventory System (FPEIS). This computerized system (EPA 1985) is maintained in EPA's Industrial Environmental Research Laboratory at Research Triangle Park, North Carolina. The system

contains the results of EPA-sponsored source testing and source testing sponsored by others. The results of more than 300 testing programs are documented. From this report, we obtained all data in the system as of June 1983. For certain source categories (stationary internal combustion engines, grain processing, aggregate processing), additional data inserted to the FPEIS between June 1983 and May 1985 were obtained.

(2) AP-42 Update for Selected Particle Size Data (EPA 1984). This 1984 report is a compilation of particle size data derived from primary source testing documents representing sources that do not have data of sufficient quality to be presented in the main body of AP-42 or for which there is no corresponding AP-42 section.

(3) Inhalable Particulate Program. The Office of Air Quality Planning and Standards (OAQPS) and the Office of Research and Development (ORD) sponsored an extensive multiyear source-testing program to develop particle size data for selected source categories. These data will greatly expand current knowledge related to particle size distributions. Source test measurements from this program were used in the data base. Final data are expected to be released over the next several months both by separate ORD report and as an integral part of AP-42.

(4) Miscellaneous Data. Source testing data available from sources other than those listed above consist of file data from testing often sponsored by state or nongovernmental groups. An effort was made to compile much of these data from contractors' private files and other miscellaneous sources.

Although all existing source test data reporting particle size distributions were probably not obtained, the data base is substantially complete. It should be noted, however, that all data in the data base have not been peer-reviewed.

## 3.2 VARIATIONS IN DATA

Data gathered into the data base come from more than 400 testing programs. These data vary widely in quality, and likely sources of error are discussed.

### 3.2.1 Errors in Measuring Point Sources

Particulate matter emitted from point sources may be measured to determine compliance with applicable emission limitations, to evaluate control equipment performance, or to establish emission factors. Many of the test methods, however, may introduce biases that can influence the validity of the results.

#### 3.2.1.1 Mass Concentration Measurement--

The most precise method of determining the mass concentration of particulate matter in a gas stream is to collect the entire volume of gas and the particulate matter and to determine the mass concentration from this sample. This procedure, however, is feasible only with a few sources (those that have very low volumetric flow rates). Various groups have developed procedures for sampling small portions of a gas stream to obtain a representative sample of the total gas stream. Examples of these procedures are EPA Reference Methods 5 and 17, American Society for Testing and materials (ASTM) Method D2928-71, and the American Society of Mechanical Engineers (ASME) Power Test Code 27. The predominant test procedure for characterization of particulate matter is EPA Reference Method 5, Determination of Particulate Emissions From Stationary Sources, Appendix A, 40 CFR 60. The quality assurance checks specified in Method 5 combined with the use of EPA Methods 1, 2, 3, and 4 help to ensure the accuracy of mass concentration determinations obtained by this procedure.

Method 5 is based on extractive filtration. Gas is extracted isokinetically; i.e., the velocity of the gas entering the sampling nozzle is equal to the gas velocity passing by the nozzle at that sampling point. The extraction is made through a nozzle to an externally heated filter held at 120° ± 14°C. The particulate matter is captured in the sampling probe and on the filter, and the filtered gases are then sent through a series of impingers to remove moisture and other components before they pass through a dry gas meter. For a test to be valid, isokinetic conditions must be maintained within ±10 percent of 100 percent. In a gas stream with both large and small particles, sampling rates lower than 100 percent isokinetic can bias the sample toward larger particles, and can strongly bias the mass concentration calculations. The reverse is true with sampling rates above 100 percent isokinetic; in this case, the bias toward smaller particles would result in an apparent mass concentration that is lower than the actual emission rates.

Establishing isokinetic sampling rates depends on the characteristics of the individual sampling train and on determination of gas velocity, gas volumetric flow rate (EPA Method 2), gas molecular weight (EPA Method 3), and gas moisture content (EPA Method 4). Procedures outlined in EPA Method 1 are used to determine the location and suitability of the sampling site and the location of the sampling points to provide a representative sample of the gas stream. Thus the use of EPA Method 5 depends on the proper use of other EPA test methods,

each of which affects whether the mass concentration data will be representative of the actual emissions from a stationary source.

3.2.1.2 Particle Size Analysis--

The cascade inertial impactor is the device most commonly used for particulate sizing. The sampling train consists of a probe, a precutter (such as a cyclone), and the cascade impactor.

The cascade inertial impactor technique provides a distribution of aerodynamic particle diameters. A cascade impactor usually has 5 to 10 stages of decreasing orifice diameters. It is usually assembled to give an alternating pattern of orifice plates and collection plates. As the orifice size decreases, the gas velocity through each orifice increases. Larger particles cannot overcome the inertial force imparted to them through the orifice and thus impact the collector plate. Because smaller particles have less inertia, the gas stream carries them to the next stage. The last stage is usually followed by a filter for the capture of the smallest particles that have escaped impaction. Gravimetric methods are used in the analysis of each stage to determine particle size distribution, geometric mass median diameter, and geometric standard deviation. The results of cascade impactors are influenced by the deposition of particulate in the probe. For example, one test indicated that at a velocity of 15 m/s, 33 percent of the 10-μm particles were collected in the probe.

Cascade impactors are typically in situ (i.e., in-stack) devices used with isokinetic sampling rates. When samples are

obtained in situ at the stack temperature, the particle size distribution should be representative of the actual particle size distribution in the duct. Failure to sample isokinetically results in a biased and unrepresentative particle size distribution. A bias toward larger particle sizes occurs with underisokinetic sampling (i.e., velocity entering nozzle is lower than the localized gas velocity), and bias toward smaller sizes occurs with overisokinetic sampling. Cascade impactors are provided in stages with nominal values for aerodynamic cut-size diameters. Each impactor should be calibrated periodically to determine the actual value of the cut-size diameter for each stage.

Cascade impactors are susceptible to several problems. First, in gas streams with high particulate loadings, quick buildup of material on the stages may shorten the available testing period. Second, particle reentrainment and bounce can bias the particle size distribution toward smaller particles. Finally, fracturing of the larger particles at the impaction stage may lead to generation of fine particulate and to a consequent bias toward small particle sizes.

Cyclones are also used for in situ and extractive aerodynamic particle sizing, but to a lesser extent than cascade impactors. The aerosol sample enters the cyclone through a tangential inlet and follows a vortex flow pattern. Particles that cannot follow the gas streamlines move outward toward the cyclone wall and, depending on cyclone geometry, gas flow rate,

and particle size, may reach the cyclone walls and be collected. The use of a series of cyclones of different geometric dimensions at a constant flow rate allows particles to be removed from a gas stream according to size. The fractionating capability of cyclones is not theoretically predictable to the degree of accuracy possible with impactors. Cyclones have an advantage over impactors in that large samples can be acquired and less particle reentrainment occurs.

Size-distribution analysis of collected particulate samples is often performed in the laboratory instead of by in situ procedures. Errors are possible because the original flue gas particle size distribution is almost impossible to reconstruct under laboratory conditions. The gas-stream state of particles or particle groups may be altered by additional agglomeration or particle breakup during sample collection. Size distribution results based on sedimentation and elutriation, centrifuging, sieving, and electronic counting are meaningful only when the effects of sample collection and redispersion are negligible or clearly known.

Microscopic analysis is regarded as the fundamental technique for counting and sizing particles. This procedure involves manual or computerized microscopic examination of a prepared slide containing a representative sample of the aerosol. The slide must be prepared carefully so that the in-stack state of the aerosol sample is not altered. Microscopic examination of particulate matter does not yield size information in terms of

aerodynamic diameters; instead, it yields information in terms of physical diameters. Aerodynamic and physical diameter data are not directly comparable.

### 3.2.2 Errors in Measuring Open Sources

Measurement of mass concentration and particle size distribution at open sources is generally regarded as less accurate than measurement of point sources. No EPA standard methods exist for sampling open sources, and sampling instrumentation, methods, and quality assurance procedures vary widely. Compared with sampling point sources, sampling of open sources is plagued by variations in source strength and difficulties associated with obtaining a sample of a representative portion of the plume.

### 3.2.3 Reconciling Differences in the Data Base

The preceding discussion has indicated that several sources of error are possible in source testing particulate data for both point and open sources. Most of the data taken from the four references listed in Section 3.1 have not undergone EPA's peer review process.

Problems encountered in attempts to reconcile differences in the data base were not completely overcome. The FPEIS (the basic reference used) did not always include information describing each test series. Also, documentation in the original reports was often inadequate. The sheer size of the data set and the scope of this study prohibited an in-depth investigation into each test series.

## 3.4 DEVELOPMENT OF INITIAL CLASSIFICATION SYSTEM

Two alternate approaches were used to develop the initial classification system accounting for the basic process and material being processed:

(1) Development of classifications by use of the computer and statistical programs relating mean values and correlation analyses applied to the entire data set.

(2) A theoretical approach based on the use of engineering judgment regarding basic processes and materials being processed.

### 3.4.1 Computerized Statistical Approach

For all the test series documenting testing of uncontrolled sources, the following were entered into a computerized data base: a process description, cumulative mass at three or four particle sizes (usually <2.5 μm, <6.0 μm, and <10 μm, but reference-dependent), and FPEIS Test Series number.

The computerized data base was subjected to two statistical approaches for development of the category system: 1) rank ordering of test series by percent of particles less than 10 μm and 2) correlation analysis by using the three or four cumulative mass values. The results were the same in both cases. The test series which were grouped together by statistical routines were in no way related by process. For example, the size distribution of emissions from an industrial boiler fired with low-sulfur coal was found to be identical to that of open fugitive emissions from an unpaved road in an iron and steel facility. Therefore, the computerized statistical approach could not be used to develop categories corresponding to basic process/material combinations.

Preceding page blank

### 3.4.2 Theoretical Approach

In the theoretical approach, engineering judgment was used to develop an initial category system according to basic processes and material being processed. The procedure involved reviewing each section of AP-42 to develop an initial list of categories. The processes and materials in each section were identified and then combined into a single list. Next, an effort was made to combine similar process/material combinations as a means of reducing the number of initial generalized categories. This initial list of generalized categories based on engineering judgment contained 33 entries.

## 3.5 DEVELOPMENT OF FINAL GENERALIZED CATEGORIES AND CORRESPONDING SIZE DISTRIBUTIONS

### 3.5.1 Development of Particle Size Distributions

After the data were coded into the data base, they were sorted according to the 33 generalized process categories. To develop the average particle size distribution for each generalized category, a replicate of the PADRE program for combining data was used. Within each category, the percentages of all particulates less than 2.5 μm in size were averaged to produce a mean value. Similarly, the values of all particulates under 6.0 μm and all under 10 μm were averaged. These three mean values were then plotted and connected with a line to obtain the particle size distribution for that category. To obtain cumulative mass values for size fractions other than 2.5, 6.0,

and 10.0 μm, a utility program that acknowledges the log-probability format of the data was used.

Results of the initial curve fitting were mixed. For some generalized categories the plots were satisfactory (<10 μm values were within ± 15 percent), for some they indicated random data scatter, and for others there were groupings of data (10-μm values clustered around two or more percentages). In this application, data scatter can be attributed to one or more of three factors:

1. Test data assigned to improper category.
2. Category too broadly defined.
3. Test data not representative of category because of unrepresentative source conditions or measurement errors.

Using the following procedures, we critically examined the plots for each generalized category for the possibility of unacceptable data scatter resulting from any of these factors:

1. Categorization of all data was verified for correctness. Potential sources of error were data entry mistakes and improper judgment in category assignment. This required going back to the original data reference to obtain more information about conditions during testing.
2. An attempt was made to arrive at a more restrictive definition of each category, which resulted in the creation of additional categories. This was usually based on the material being processed. When the categories were more restrictively defined, some test series were reassigned to a different category.
3. Extreme values (high or low) were critically examined. This entailed reexamination of the original references. In some cases the extreme values could be attributed to a special testing condition. In other cases the data were obviously illogical and could only be attributed to measurement or reporting error. Any data that were

determined to be unrepresentative or in error were removed from the data base.

Even after these procedures were applied, some categories still had far more data scatter than others. This could be attributed to real variations in source emissions or to measurement or reporting errors.

The procedures described resulted in expansion of the number of generalized categories from 33 to 43 categories.

### 3.5.2 Development of Final Categories

Forty-three categories were considered to be an undesirably large number for the following reasons:

1. Fewer categories would be less cumbersome for local and state agencies in developing SIP revisions.

2. These data probably do not justify the implied precision of 43 categories; e.g., differences of five percentage points in cumulative mass probably could be just as attributable to data "noise" as to real source differences.

An attempt was made to reduce the number of categories by rank-ordering all categories by cumulative mass of particulates less than 10 μm in size. When categories had cumulative mass percentages that were representative of related process/materials combinations, these categories were combined. In addition to the rank ordering procedure, categories were also eliminated when they represented source categories for which particle size distributions were already in, or planned to be in AP-42. The result was a total of nine categories.

### 3.5.3 Assignment of Generic Categories to Particulate Sources Listed in AP-42

The form of the data presentation was determined by the intended end use of the data, i.e., emission inventories. Because the basic reference for emission factors is AP-42, it was decided to link the data presentation to AP-42 organization. A tabular presentation was developed that lists the particular process name and number, and the assigned generalized particle size distribution. These data are shown in Table 3-1.

Table 3-2 lists the generalized particle size categories, the percent cumulative mass of particles in the <2.5 μm, <6.0 μm and <10 μm size categories. Data supporting each category, and a particle size distribution for each category are shown in Appendix A.

## TABLE 3-1. PARTICLE SIZE CATEGORY BY AP-42 SECTION

| AP-42 Section | Source Category | Category Number[c] |
|---|---|---|
| | External combustion | |
| 1.1 | Bituminous coal combustion | a |
| 1.2 | Anthracite coal combustion | a |
| 1.3 | Fuel oil combustion | a |
| | Utility, residual oil | a |
| | Industrial, residual oil | a |
| | Utility, distillate oil | a |
| | Commercial, residual oil | a |
| | Commercial, distillate | a |
| | Residential, distillate | a |
| 1.4 | Natural gas combustion | a |
| 1.5 | Liquefied petroleum gas | a |
| 1.6 | Wood waste combustion in boilers | a |
| 1.7 | Lignite, combustion | a |
| 1.8 | Bagasse Combustion | b |
| 1.9 | Residential fireplaces | a |
| 1.10 | Wood stoves | a |
| 1.11 | Waste oil combustion | 2 |
| | Solid waste disposal | |
| 2.1 | Refuse Incinerators | b |
| 2.3 | Conical burners (wood waste) | 2 |
| | Internal combustion engine | |
| | Highway vehicles[d] | a |
| 3.2 | Off highway | 1 |
| | Chemical process | |
| 5.4 | Charcoal production | 9 |
| 5.8 | Hydrofluoric acid | |
| | Spar drying | 3 |
| | Spar handling | 3 |
| | Transfer | 3 |
| 5.10 | Paint | 4 |
| 5.11 | Phosphoric acid (thermal process) | a |
| 5.12 | Phthalic anhydride | 9 |
| 5.16 | Sodium carbonate | a |
| 5.17 | Sulfuric acid | b |
| | Food and agricultural | |
| 6.1 | Alfalfa dehydrating | |
| | Primary cyclone | b |
| | Meal collector cyclone | 7 |
| | Pellet cooler cyclone | 7 |
| | Pellet regrind cyclone | 7 |
| 6.2 | Coffee roasting | 8 |
| 6.3 | Cotton ginning | b |
| 6.4 | Feed and grain mills and elevators | |
| | Unloading | b |
| | Grain elevators | 6 |
| | Grain processing | 7 |
| 6.5 | Fermentation | 6&7 |
| 6.7 | Meat smokehouses | 9 |
| 6.8 | Ammonium nitrate fertilizers | a |
| 6.10 | Phosphate fertilizers | 3 |
| 6.10.3 | Ammonium phosphates | |
| | Reactor/ammoniator-granulator | 4 |
| | Dryer/cooler | 4 |
| 6.11 | Starch manufacturing | 7 |
| 6.14 | Urea manufacturing | 2 |
| 6.16 | Defoliation and harvesting of cotton | |
| | Trailer loading | 6 |
| | Transport | 6 |
| 6.17 | Harvesting of grain | |
| | Harvesting machine | 6 |
| | Truck loading | 6 |
| | Field transport | 6 |
| 6.18 | Ammonium sulfate manufacturing | |
| | Rotary dryer | b |
| | Fluidized bed dryer | b |
| | Metallurgical industry | |
| 7.1 | Primary aluminum production | |
| | Bauxite grinding | 4 |
| | Aluminum hydroxide calcining | 5 |
| | Anode baking furnace | 9 |
| | Prebake cell | a |
| | Vertical Soderberg | 8 |
| | Horizontal Soderberg | a |
| 7.2 | Coke manufacturing | a |
| 7.3 | Primary copper smelting | a |
| 7.4 | Ferroalloy production | a |
| 7.5 | Iron and steel production | |
| | Blast furnace | |
| | Slips | a |
| | Cast house | a |
| | Sintering | |
| | Windbox | a |
| | Sinter discharge | a |
| | Basic oxygen furnace | a |
| | Electric arc furnace | a |
| 7.6 | Primary lead smelting | a |
| 7.7 | Zinc smelting | 8 |
| 7.8 | Secondary aluminum | |
| | Sweating furnace | 8 |
| | Smelting | |
| | Crucible furnace | 8 |
| | Reverberatory furnace | a |
| 7.9 | Secondary copper smelting and alloying | 8 |
| 7.10 | Gray iron foundries | a |

a. Categories with particle size data specific to process included in the main body of the text.
b. Categories with particle size data specific to process included in Appendix C.1.
c. Data for each numbered category are shown in Appendix A.
d. Highway vehicles data are reported in AP-42 Volume II: Mobile Sources.

TABLE 3.1 (continued).

| AP-42 Section | Source Category | Category Number[c] |
|---|---|---|
| | Metallurgical industry (cont.) | |
| 7.11 | Secondary lead processing | a |
| 7.12 | Secondary magnesium smelting | 8 |
| 7.13 | Steel foundaries | |
| | melting | b |
| 7.14 | Secondary zinc smelting | 8 |
| 7.15 | Storage battery production | b |
| 7.18 | Leadbearing ore crushing and grinding | 4 |
| | Mineral products | |
| 8.1 | Asphaltic concrete plants | |
| | Process | a |
| 8.3 | Bricks and related clay products | |
| | Raw materials handling | |
| | Dryers, grinders, etc. | b |
| | Tunnel/periodic kilns | |
| | Gas fired | a |
| | Oil fired | a |
| | Coal fired | a |
| 8.5 | Castable refractories | |
| | Raw material dryer | 3 |
| | Raw material crushing and screening | 3 |
| | Electric arc melting | 8 |
| | Curing oven | 3 |
| 8.6 | Portland cement manufacturing | |
| | Dry process | |
| | Kilns | a |
| | Dryers, grinders, etc. | 4 |
| | Wet process | |
| | Kilns | a |
| | Dryers, grinders, etc. | 4 |
| 8.7 | Ceramic clay manufacturing | |
| | Drying | 3 |
| | Grinding | 4 |
| | Storage | 3 |
| 8.8 | Clay and fly ash sintering | |
| | Fly ash sintering, crushing, screening and yard storage | 5 |
| | Clay mixed with coke | |
| | Crushing, screening, and yard storage | 3 |
| 8.9 | Coal cleaning | 3 |
| 8.10 | Concrete batching | 3 |
| 8.11 | Glass fiber manufacturing | |
| | Unloading and conveying | 3 |
| | Storage bins | 3 |
| | Mixing and weighing | 3 |
| | Glass furnace - wool | a |
| | Glass furnace - textile | a |
| 8.13 | Glass manufacturing | a |
| 8.14 | Gypsum manufacturing | |
| | Rotary ore dryer | a |
| | Roller mill | 4 |
| | Impact mill | 4 |
| | Flash calciner | a |
| | Continuous kettle calciner | a |
| 8.15 | Lime manufacturing | a |
| 8.16 | Mineral wool manufacturing | |
| | Cupola | 8 |
| | Reverberatory furnace | 8 |
| | Blow chamber | 8 |
| | Curing oven | 9 |
| | Cooler | 9 |
| 8.18 | Phosphate rock processing | |
| | Drying | a |
| | Calcining | a |
| | Grinding | b |
| | Transfer and storage | 3 |
| 8.19.1 | Sand and gravel processing | |
| | Continuous drop | |
| | Transfer station | a |
| | Pile formation - stacker | a |
| | Batch drop | a |
| | Active storage piles | a |
| | Vehicle traffic unpaved road | a |
| 8.19.2 | Crushed stone processing | |
| | Dry crushing | |
| | Primary crushing | a |
| | Secondary crushing and screening | a |
| | Tertiary crushing and screening | 3 |
| | Recrushing and screening | 4 |
| | Fines mill | 4 |
| | Screening, conveying, and handling | a |
| 8.22 | Taconite ore processing | |
| | Fine crushing | 4 |
| | Waste gas | a |
| | Pellet handling | 4 |
| | Grate discharge | 5 |
| | Grate feed | 4 |
| | Bentonite blending | 4 |
| | Coarse crushing | 3 |
| | Ore transfer | 3 |
| | Bentonite transfer | 4 |
| | Unpaved roads | a |
| 8.23 | Metallic minerals processing | a |
| 8.24 | Western surface coal mining | a |
| | Wood processing | |
| 10.1 | Chemical wood pulping | a |
| | Miscellaneous sources | |
| 11.2 | Fugitive dust | a |

a. Categories with particle size data specific to process included in the main body of the text.
b. Categories with particle size data specific to process included in Appendix C.1.
c. Data for each numbered category are shown in Appendix A.

TABLE 3-2. FINAL GENERALIZED PARTICLE SIZE DISTRIBUTION CATEGORIES
(% cumulative mass)

| Generic Category Number | Process | Material | <2.5 μm | | | | 6.0 μm | | | | 10.0 μm | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mass Less Than | Min | Max | S.D.[a] | Mass Less Than | Min | Max | S.D. | Mass Less Than | Min | Max | S.D. |
| 1 | Stationary internal combustion engines | Gasoline and diesel fuel | 90 | 78 | 99 | 11 | 93 | 86 | 99 | 7 | 96 | 92 | 99 | 4 |
| 2 | Combustion | Mixed fuels | 45 | 32 | 70 | 17 | 70 | 49 | 84 | 14 | 79 | 56 | 87 | 12 |
| 3 | Mechanically generated | Aggregate, unprocessed ores | 15 | 3 | 35 | 7 | 34 | 15 | 65 | 13 | 51 | 23 | 81 | 14 |
| 4 | Mechanically generated | Uranium, processed ores | 30 | 1 | 51 | 19 | 62 | 17 | 83 | 17 | 85 | 70 | 93 | 7 |
| 5 | Calcining and other heat reaction processes | Aggregate, unprocessed ores | 17 | 3 | 42 | 11 | 35 | 9 | 74 | 19 | 50 | 14 | 84 | 19 |
| 6 | Grain handling | Grain | 1 | 0 | 2 | 1 | 7 | 3 | 12 | 3 | 15 | 6 | 25 | 7 |
| 7 | Grain processing | Grain | 23 | 17 | 34 | 9 | 43 | 35 | 48 | 7 | 61 | 56 | 65 | 5 |
| 8 | Melting, smelting, refining | Metals, except aluminum | 82 | 63 | 99 | 12 | 89 | 75 | 99 | 9 | 92 | 80 | 99 | 7 |
| 9 | Condensation, hydration, absorption, prilling and distillation | All | 78 | 59 | 99 | 17 | 91 | 61 | 99 | 12 | 94 | 71 | 99 | 9 |

[a] Standard Deviation

# SECTION 4

# DEVELOPMENT OF GENERALIZED PARTICLE SIZE DISTRIBUTIONS FOR CONTROLLED SOURCES

## 4.1 CALCULATION OF THE SIZE DISTRIBUTION FOR A CONTROLLED SOURCE

Section 3 presents detailed procedures for developing a particle size distribution for uncontrolled sources. The purpose of this section is to describe the development of a procedure to allow calculation of a size distribution for a controlled source.

The large number of possible source/control combinations prompted the use of generalized data by type of control device and fractional control efficiency. This approach is based on Table A-2 in AP-42. This table was updated to reflect recent technology and is presented here as Table 4-1. The primary reference for the update was EPA's Control Techniques for Particulate Emissions from Stationary Sources (EPA 1980). However, other references were also used (EPA 1977; Cushing undated).

To use Table 4-1, the analyst must first develop the uncontrolled size distribution according to the procedures given in Section 4. The fractional control efficiencies are applied to the uncontrolled size distribution to calculate the controlled size distribution. This procedure is illustrated in Section 5.

TABLE 4-1. AVERAGE COLLECTION EFFICIENCIES OF VARIOUS PARTICULATE CONTROL DEVICES.[a]
(percent)

| Type of collector | Particle size, μm | | | |
|---|---|---|---|---|
| | Overall | 0 - 2.5 | 2.5 - 6 | 6 - 10 |
| Baffled settling chamber | -- | NR | 0-6 | 6-20 |
| Simple (high-throughput) cyclone | 80 | 50-70 | 70-83 | 83-90 |
| High-efficiency and multiple cyclones | 90-99 | 80-95 | 95-98 | 99 |
| Electrostatic precipitator (ESP) | 99.5 | 96.1-99.5 | 99.7 | 99.3-99.8 |
| Packed-bed scrubber | 90-95 | 90-99.6 | 98-99.6 | 98-99.6 |
| Venturi scrubber | 96-97 | 93-97 | 94.0-98.3 | 98.3-99.0 |
| Wet-impingement scrubber | 90 | 8-74 | 74-98 | 90-98 |
| Fabric filter | 99.3-99.9 | 99.3-99.9 | 99.7-99.9 | 99.8-99.9 |

[a] The data shown represent an average of actual efficiencies. The efficiencies are representative of well-designed and well-operated control equipment. Site-specific factors (e.g., type of particulate being collected, varying pressure drops across scrubbers, maintenance of equipment) will affect the collection efficiencies. The efficiencies shown are intended to provide guidance for estimating control equipment performance when site-specific data are not available.

NR Not reported.

## SECTION 5

## HOW TO USE THE GENERALIZED PARTICLE SIZE DISTRIBUTIONS AND CONTROL EFFICIENCY DATA

Appendix B contains a calculation sheet to assist the analyst in preparing particle size specific emission estimates.

### 5.1 UNCONTROLLED SOURCES

The following instructions apply to each particulate emission source for which a particle size distribution is desired and for which no source specific particle size information is give elsewhere in this AP-42:

1. Identify and review the AP-42 section dealing with the source.
2. Obtain the uncontrolled emission factor from the main text of AP-42 and calculate uncontrolled total particulate emissions.
3. To develop the size distribution, for sources which do not have source specific in this AP-42, obtain the generalized particle size distribution category number from Table 3-1.
4. Obtain the particle size distribution for the appropriate category from Table 3-2. Apply the particle size distribution to the uncontrolled particulate emissions.

### 5.2 CONTROLLED SOURCES

To calculate the size distribution for a source with a particulate control device the used should first calculate the

uncontrolled size distributions. Next, the fractional control efficiency for the control device should be estimated using Table 4-1. The Calculation Sheet (Appendix B) allows the user to record the type of control device and the collection efficiency from Table 4-1, the mass in the size range before and after control, and the cumulative mass. The user should note that the uncontrolled size data is expressed in cumulative fraction less than the stated size. The control efficiency data applies only to the size range indicated and is not cumulative.

## 5.3 EXAMPLE CALCULATION

An example calculation is shown on Figure 5-1. After recording process identifiers, uncontrolled total particulate emissions, uncontrolled size-specific emissions, and controlled size specific emission are then calculated.

FIGURE 5-1. EXAMPLE CALCULATION FOR DETERMINING UNCONTROLLED AND CONTROLLED PARTICLE SIZE-SPECIFIC EMISSIONS.

SOURCE IDENTIFICATION

Source name and address: ABC Brick Manufacturing
24 Dusty Way
Anywhere, USA

Process description: Dryers/Grinders

AP-42 category: 8.3 Bricks and Related Clay Products

Uncontrolled AP-42 emission factor: 96 lbs/ton (units)

Activity parameter: 63,700 tons/year (units)

Uncontrolled emissions: 3057.6 tons/year (units)

UNCONTROLLED SIZE DISTRIBUTION

Category name: Mechanically Generated/Aggregate, Unprocessed Ores

Category number: 3

| | Particle size, μm | | |
|---|---|---|---|
| | ≤ 2.5 | ≤ 6 | ≤ 10 |
| Generic distribution, Cumulative percent less than or equal to: | 15 | 34 | 51 |
| Mass in size range, (units = tons/year): | 458.6 | 1039.6 | 1559.4 |

CONTROLLED SIZE DISTRIBUTION

Type of control device: Fabric Filter

| | Particle size, μm | | |
|---|---|---|---|
| | 0-2.5 | 2.5-6 | 6-10 |
| Collection efficiency Table 4-1: | 99.6 | 99.8 | 99.9 |
| Mass in size range* before control (units=tons/year): | 458.6 | 581.0 | 519.8 |
| Mass in size range after control: | 1.83 | 1.16 | 0.52 |
| Cumulative mass: | | 2.99 | 3.51 |

* Note that uncontrolled size data is cumulative percent less than. Control efficiency data applies only to size range and is not cumulative.

## REFERENCES

Cushing, K. M. Undated. Development of Horizontal Elutriators for Sampling Inhalable Particulate Fugitive Emissions. Southern Research Institute, Birmingham, Alabama.

Environmental Protection Agency. 1977. Operation and Maintenance of Particulate Control Devices on Coal-Fired Utility Boilers. EPA-600/2-77-129.

Environmental Protection Agency. 1982. Control Techniques for Particulate Emissions From Stationary Sources--Volumes 1 and 2. EPA-450/3-81-005a.

Environmental Protection Agency. 1984. AP-42 Update for Selected Particle Size Data. Prepared by Engineering-Science, Durham, NC for Air Management Technology Branch, Research Triangle Park, NC 27711.

Environmental Protection Agency. 1985. Fine Particulate Emission Inventory System. Air and Energy Engineering Research Laboratory, Research Triangle Par, NC 27711.

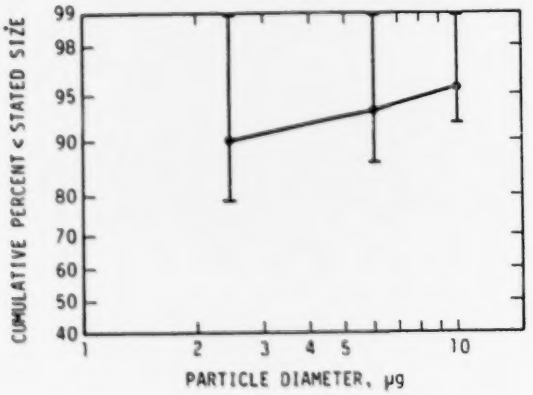
# APPENDIX A

# GENERALIZED PARTICLE SIZE DISTRIBUTIONS

This appendix contains two sheets for each of the nine generalized particle size categories. The first sheet presents category identifiers, a plot of the size distribution, and a particle size summary. The second sheet for each category lists the data that were used to develop the category distribution.

Category: 1
Process: Stationary Internal Combustion Engines
Material: Gasoline and Diesel Fuel

Category 1 describes emissions from stationary internal combustion engines. The particulate emissions are generated from fuel combustion.




| Particle size, µm | Cumulative % less than or equal to stated size (uncontrolled) | Minimum Value | Maximum Value | Standard Deviation |
|---|---|---|---|---|
| 1.0[a] | 82 | | | |
| 2.0[a] | 88 | | | |
| 2.5 | 90 | 78 | 99 | 11 |
| 3.0[a] | 90 | | | |
| 4.0[a] | 92 | | | |
| 5.0[a] | 93 | | | |
| 6.0 | 93 | 86 | 99 | 7 |
| 10.0 | 96 | 92 | 99 | 4 |

[a] Value calculated from data reported at 2.5, 6.0, and 10.0 µm. No statistical parameters are given for the calculated value.

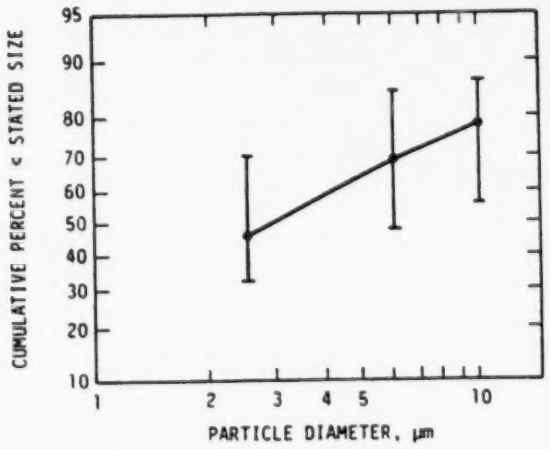
Category: 1
Process: Stationary Internal Combustion Engines
Material: Gasoline and Diesel Fuel

| Source description | Cumulative percent less than or equal to stated size | | | Ref. |
|---|---|---|---|---|
| | 2.5 µm | 6.0 µm | 10.0 µm | |
| Stationary IC engine-#2 diesel oil | 94 | 95 | 96 | 9 |
| Stationary IC engine-digester gas | 99 | 99 | 99 | 9 |
| Stationary IC engine-#2 fuel oil | 78 | 86 | 92 | 1/165[a] |

[a] Reference 1, FPEIS Test Series 165

Category: 2
Process: Combustion
Material: Mixed Fuels

Category 2 contains boilers firing a mixture of fuels regardless of the fuel combination. The fuels include gas, coal, coke, and petroleum. Particulate emissions are generated as the result of firing these miscellaneous fuels.




| Particle size, µm | Cumulative % less than or equal to stated size (uncontrolled) | Minimum Value | Maximum Value | Standard Deviation |
|---|---|---|---|---|
| 1.0[a] | 23 | | | |
| 2.0[a] | 40 | | | |
| 2.5 | 45 | 32 | 70 | 17 |
| 3.0[a] | 50 | | | |
| 4.0[a] | 58 | | | |
| 5.0[a] | 64 | | | |
| 6.0 | 70 | 49 | 84 | 14 |
| 10.0 | 79 | 56 | 87 | 12 |

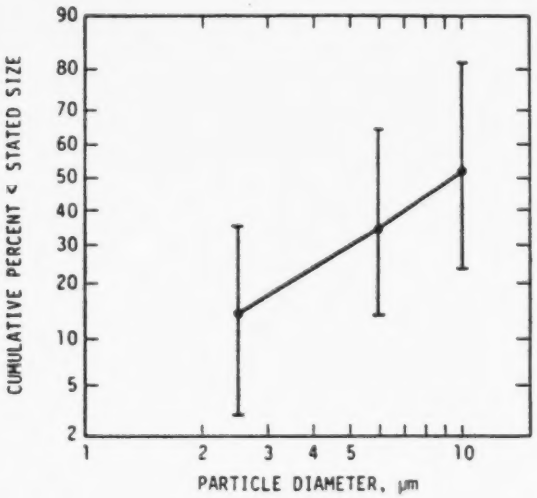
[a] Value calculated from data reported at 2.5, 6.0, and 10.0 µm. No statistical parameters are given for the calculated value.

Category: 2
Process: Combustion
Material: Mixed Fuels

| Source description | Cumulative percent less than or equal to stated size | | | Ref. |
|---|---|---|---|---|
| | 2.5 μm | 6.0 μm | 10.0 μm | |
| Ind. boiler-petroleum/coke | 35 | 78 | 87 | 1/163 |
| Util. boiler-80% coal/20% coke | 32 | 65 | 81 | 1/73 |
| Util. boiler-75% coke/25% gas | 63 | 84 | 87 | 1/108 |
| Util. boiler-10% gas/90% coal | 70 | 82 | 86 | 1/82 |
| Util. boiler-petroleum/coke | 34 | 63 | 78 | 1/75 |
| Util. boiler-petroleum/coke | 38 | 49 | 56 | 1/100 |

Category: 3
Process: Mechanically Generated
Material: Aggregate, Unprocessed Ores

Category 3 covers material handling and processing of aggregate and unprocessed ore. This broad category includes emissions from milling, grinding, crushing, screening, conveying, cooling, and drying of material. Emissions are generated through either the movement of the material or the interaction of the material with mechanical devices.




| Particle size, µm | Cumulative % less than or equal to stated size (uncontrolled) | Minimum Value | Maximum Value | Standard Deviation |
|---|---|---|---|---|
| 1.0[a] | 4 | | | |
| 2.0[a] | 11 | | | |
| 2.5 | 15 | 3 | 35 | 7 |
| 3.0[a] | 18 | | | |
| 4.0[a] | 25 | | | |
| 5.0[a] | 30 | | | |
| 6.0 | 34 | 15 | 65 | 13 |
| 10.0 | 51 | 23 | 81 | 14 |

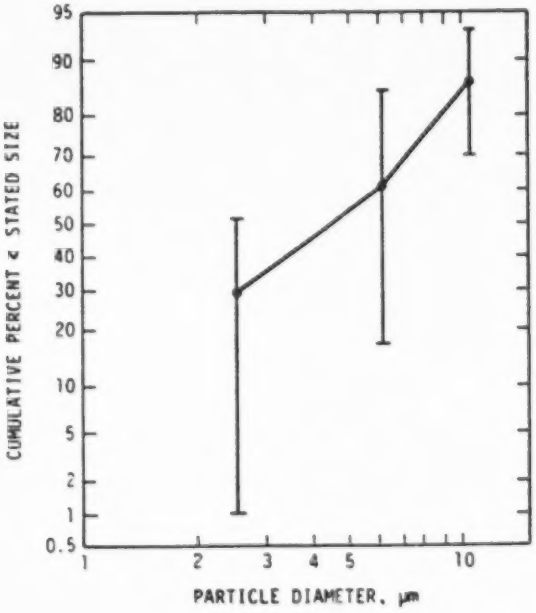
[a] Value calculated from data reported at 2.5, 6.0, and 10.0 µm. No statistical parameters are given for the calculated value.

Category: 3
Process: Mechanically Generated
Material: Aggregate, Unprocessed Ore

| Source description | Cumulative percent less than or equal to stated size | | | Ref. |
|---|---|---|---|---|
| | 2.5 µm | 6.0 µm | 10.0 µm | |
| Asphalt batch-dry/screen./mix. | 15 | 21 | 44 | 1/41 |
| Asphalt concrete-drum mix | 21 | 52 | 66 | 1/299 |
| Cement-clinker cooler | 8 | 17 | 32 | 1/86 |
| Clay aggregate-clinker cooler | 16 | 30 | 40 | 7 |
| Clay aggregate-clinker cooler | 15 | 26 | 38 | 2 |
| Copper ore-conveying | 10 | 31 | 53 | 1/310 |
| Copper ore-crushing | 18 | 34 | 42 | 1/310 |
| Copper ore-crushing | 12 | 25 | 50 | 1/309 |
| Copper ore-crushing | 11 | 22 | 43 | 1/329 |
| Copper ore-loadout | 5 | 27 | 43 | 1/345 |
| Copper ore-truck dump | 14 | 49 | 81 | 1/339 |
| Feldspar milling | 11 | 23 | 37 | 4 |
| Fluorspar processing-rotary drum dryer | 10 | 30 | 48 | 2 |
| Gold-ore crushing/conveying/storage | 16 | 37 | 62 | 1/335 |
| Gypsum-rock dryer | 10 | 30 | 39 | 1/358 -360 |
| Molybdenum-screening | 21 | 46 | 70 | 1/334 |
| Molybdenum-screening | 27 | 55 | 72 | 1/333 |
| Phosphate rock-dryer | 20 | 41 | 60 | 1/94 |
| Sodium carbonate-drying | 22 | 65 | 69 | 1/376 |
| Sodium carbonate-drying | 10 | 15 | 23 | 1/378 |
| Talc-grinding | 18 | 43 | 60 | 4 |
| Vanadium ore-dryer | 12 | 33 | 44 | 1/290 |
| Vanadium ore-dryer | 12 | 31 | 60 | 1/337 |
| Vanadium ore-drying/grinding | 13 | 36 | 58 | 1/338 |
| Zinc ore-crushing | 3 | 19 | 38 | 1/344b |
| Zinc ore-crushing/screening/conveying | 7 | 30 | 48 | 1/334a |
| Zinc ore-dryer | 35 | 41 | 62 | 1/343 |
| Zinc ore-screening | 26 | 52 | 64 | 1/344c |
| Zinc ore-screw conveying | 7 | 22 | 29 | 1/344d |

Category: 4
Process: Mechanically Generated
Material: Uranium, Processed Ores

Category 4 covers material handling and processing of uranium and processed ores. While similar to Category 3, uranium and processed ores can be expected to have a greater size consistency than unprocessed ores. Particulate emissions are generated as a result of agitating the materials by screening or transfer, during size reduction of the materials by crushing and grinding, or by drying.




| Particle size, μm | Cumulative % less than or equal to stated size (uncontrolled) | Minimum Value | Maximum Value | Standard Deviation |
|---|---|---|---|---|
| 1.0[a] | 6 | | | |
| 2.0[a] | 21 | | | |
| 2.5 | 30 | 1 | 51 | 19 |
| 3.0[a] | 36 | | | |
| 4.0[a] | 48 | | | |
| 5.0[a] | 58 | | | |
| 6.0 | 62 | 17 | 83 | 17 |
| 10.0 | 85 | 70 | 93 | 7 |

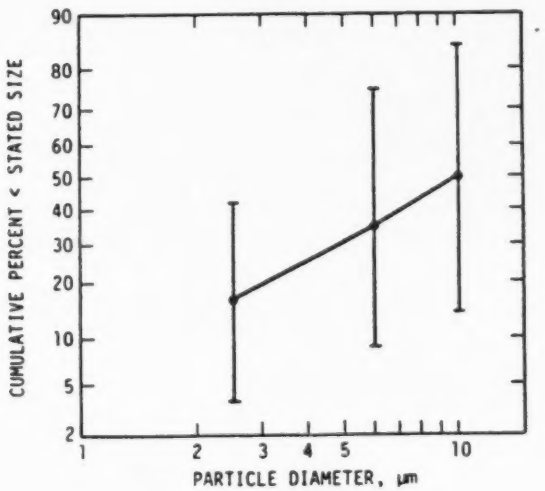
[a] Value calculated from data reported at 2.5, 6.0, and 10.0 μm. No statistical parameters are given for the calculated value.

Category: 4
Process: Mechanically Generated
Material: Uranium, Processed Ores

| Source description | Cumulative percent less than or equal to stated size | | | Ref. |
|---|---|---|---|---|
| | 2.5 μm | 6.0 μm | 10.0 μm | |
| Ammonium sulfate-dryer | 1 | 17 | 70 | 1/163 |
| Ammonium sulfate-dryer | 8 | 53 | 83 | 1/383 |
| Clay-dryer | 37 | 75 | 90 | 1/88 |
| Clay mfg.-milling | 5 | 52 | 85 | 1/381 |
| Clay mfg.-milling | 14 | 59 | 86 | 1/384 |
| Clay mfg.-Raymond mill | 50 | 52 | 85 | 1/96 |
| Potassium chloride-dryer | 22 | 64 | 85 | 1/350 |
| Potassium chloride-dryer | 19 | 68 | 89 | 1/386 |
| Salt-dryer | 49 | 59 | 69 | 1/53 |
| Salt-dryer | 36 | 77 | 92 | 1/52 |
| Uranium ore-crusher, grizzly and transfer points | 51 | 75 | 87 | 1/284 |
| Uranium ore-fine ore bin exhaust | 51 | 83 | 93 | 1/285 |
| Uranium ore-loading | 45 | 77 | 88 | 1/286 |

Category: 5
Process: Calcining and other Heat Reaction Processes
Material: Aggregate, Unprocessed Ores

Category 5 covers the use of calciners and kilns in processing a variety of aggregates and unprocessed ores. Emissions are generated as a result of these high temperature operations.




| Particle size, µm | Cumulative % less than or equal to stated size (uncontrolled) | Minimum Value | Maximum Value | Standard Deviation |
|---|---|---|---|---|
| 1.0[a] | 6 | | | |
| 2.0[a] | 13 | | | |
| 2.5 | 17 | 3 | 42 | 11 |
| 3.0[a] | 20 | | | |
| 4.0[a] | 26 | | | |
| 5.0[a] | 31 | | | |
| 6.0 | 35 | 9 | 74 | 19 |
| 10.0 | 50 | 14 | 84 | 19 |

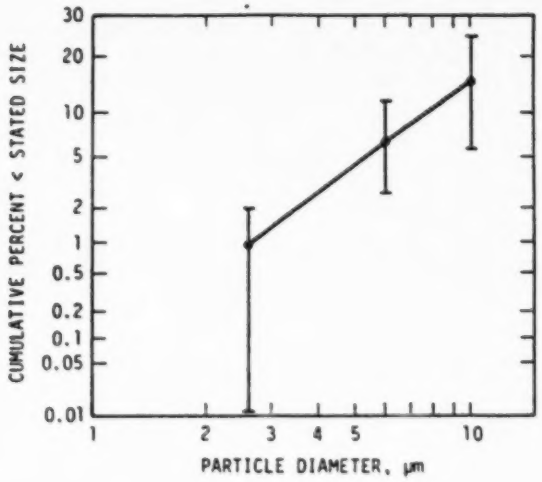
[a] Value calculated from data reported at 2.5, 6.0, and 10.0 µm. No statistical parameters are given for the calculated value.

Category: 5
Process: Calcining and Other Heat Reaction Processes
Material: Aggregate, Unprocessed Ore

| Source description | Cumulative percent less than or equal to stated size | | | Ref. |
|---|---|---|---|---|
| | 2.5 μm | 6.0 μm | 10.0 μm | |
| Brick mfg.-kiln/dry | 25 | 50 | 70 | 1/354 |
| Brick mfg.-kiln/dry | 21 | 44 | 62 | 1/33 |
| Cement mfg.-kiln | 42 | 74 | 84 | 1/298 |
| Cement mfg.-rotary kiln | 18 | 38 | 57 | 1/80 |
| Clay aggregate-rotary kiln | 14 | 29 | 42 | 2 |
| Gypsum-flash calciners | 23 | 57 | 75 | 1/295 |
| Iron ore benefication-grate kiln system | 18 | 28 | 35 | 8 |
| Lime mfg.-rotary kiln | 3 | 9 | 14 | 1/330 |
| Lime mfg.-rotary kiln | 27 | 56 | 67 | 1/294 |
| Lime mfg.-rotary kiln | 3 | 14 | 35 | 1/295 |
| Pulp/paper-lime recovery kiln | 23 | 34 | 49 | 1/104 -107 |
| Shale aggregate plant-rotary kiln | 3 | 13 | 25 | 2 |
| Sodium carbonate-calcining | 23 | 40 | 53 | 1/375 |
| Sodium carbonate-calcining | 19 | 39 | 50 | 1/377 |
| Taconite proc.-preheat | 4 | 14 | 45 | 1/348 |
| Vanadium ore-kiln drying | 3 | 21 | 43 | 1/289 |

Category: 6
Process: Grain Handling
Material: Grain

Category 6 contains various grain handling (versus grain processing) operations. These processes could include material transfer, ginning and other miscellaneous handling of grain. Emissions are generated by mechanical agitation of the material.




| Particle size, µm | Cumulative % less than or equal to stated size (uncontrolled) | Minimum Value | Maximum Value | Standard Deviation |
|---|---|---|---|---|
| 1.0[a] | .07 | | | |
| 2.0[a] | .60 | | | |
| 2.5 | 1 | 0 | 2 | 1 |
| 3.0[a] | 2 | | | |
| 4.0[a] | 3 | | | |
| 5.0[a] | 5 | | | |
| 6.0 | 7 | 3 | 12 | 3 |
| 10.0 | 15 | 6 | 25 | 7 |

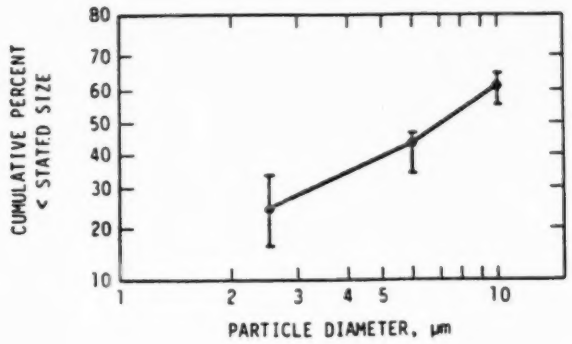
[a] Value calculated from data reported at 2.5, 6.0, and 10.0 µm. No statistical parameters are given for the calculated value.

Category: 6
Process: Grain Handling
Material: Grain

| Source description | Cumulative percent less than or equal to stated size | | | Ref. |
|---|---|---|---|---|
| | 2.5 μm | 6.0 μm | 10.0 μm | |
| Cotton ginning-roller gin, bale press | 1 | 6 | 13 | 5 |
| Cotton ginning-roller gin, gin stand | 1 | 7 | 17 | 5 |
| Cotton ginning-saw gin, bale press | 1 | 3 | 6 | 5 |
| Cotton ginning-saw gin, gin stand | 0 | 5 | 14 | 5 |
| Rice-dryer | 2 | 12 | 25 | 1/228 |

Category: 7
Process: Grain Processing
Material: Grain

Category 7 includes grain processing operations such as drying, screening, grinding and separation. The particulate emissions are generated during forced-air flow, separation or size reduction.




| Particle size, µm | Cumulative % less than or equal to stated size (uncontrolled) | Minimum Value | Maximum Value | Standard Deviation |
|---|---|---|---|---|
| 1.0[a] | 8 | | | |
| 2.0[a] | 18 | | | |
| 2.5 | 23 | 17 | 34 | 9 |
| 3.0[a] | 27 | | | |
| 4.0[a] | 34 | | | |
| 5.0[a] | 40 | | | |
| 6.0 | 43 | 35 | 48 | 7 |
| 10.0 | 61 | 56 | 65 | 5 |

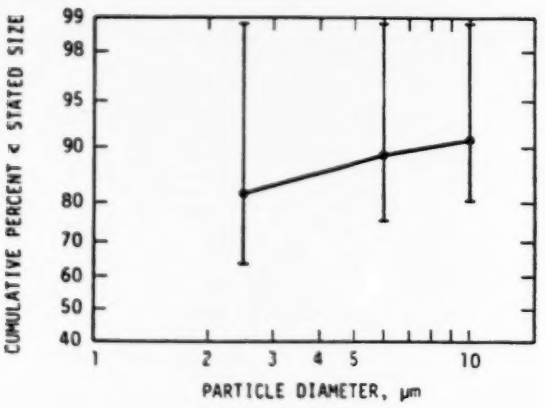
[a] Value calculated from data reported at 2.5, 6.0, and 10.0 µm. No statistical parameters are given for the calculated value.

Category: 7
Process: Grain Processing
Material: Grain

| Source description | Cumulative percent less than or equal to stated size | | | Ref. |
|---|---|---|---|---|
| | 2.5 μm | 6.0 μm | 10.0 μm | |
| Agricultural feed-production | 19 | 46 | 65 | 1/154 |
| Cereal-dryer | 34 | 48 | 56 | 2 |
| Cotton gin-battery condenser effluent | 17 | 35 | 61 | 1/27 |

Category: 8
Process: Melting, Smelting, Refining
Material: Metals, except Aluminum

Category 8 includes the melting, smelting, and refining of metals (including glass) other than aluminum. All primary and secondary production processes for these materials which involve a physical or chemical change are included in this category. Materials handling and transfer are not included. Particulate emissions are generated as a result of high-temperature melting, smelting, and refining.




| Particle size, μm | Cumulative % less than or equal to stated size (uncontrolled) | Minimum Value | Maximum Value | Standard Deviation |
|---|---|---|---|---|
| 1.0[a] | 72 | | | |
| 2.0[a] | 80 | | | |
| 2.5 | 82 | 63 | 99 | 12 |
| 3.0[a] | 84 | | | |
| 4.0[a] | 86 | | | |
| 5.0[a] | 88 | | | |
| 6.0 | 89 | 75 | 99 | 9 |
| 10.0 | 92 | 80 | 99 | 7 |

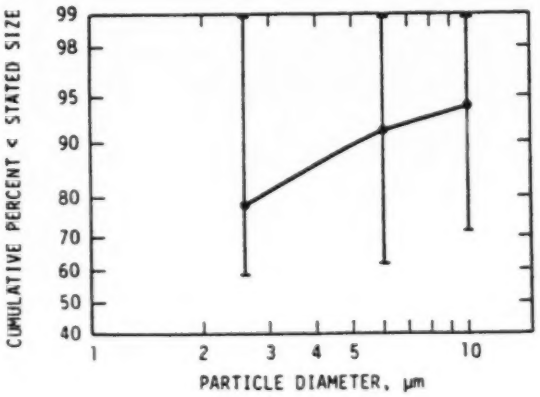
[a] Value calculated from data reported at 2.5, 6.0, and 10.0 μm. No statistical parameters are given for the calculated value.

Category: 8
Process: Melting, Smelting, Refining
Material: Metals, except aluminum

| Source description | Cumulative percent less than or equal to stated size | | | Ref. |
|---|---|---|---|---|
| | 2.5 μm | 6.0 μm | 10.0 μm | |
| Borax-fusing furnace | 88 | 98 | 99 | 1/90 |
| Copper-smelter | 96 | 99 | 99 | 1/2 |
| FE. prod.-ferrosilicon | 97 | 99 | 99 | 1/51 |
| Ferroalloy-EAF | 83 | 84 | 94 | 1/280 |
| Glass-manufacturing | 91 | 93 | 95 | 1/219, 223, 224 |
| Gray iron-cupola | 93 | 98 | 99 | 1/54 |
| Gray iron-scrap cupola | 95 | 99 | 99 | 1/55 |
| Iron & steel prod.-iron cupola | 92 | 96 | 98 | 1/42 |
| Mineral wool-cupola | 67 | 82 | 91 | 1/123 |
| Steel foundry-EAF | 69 | 79 | 82 | 1/308 |
| Steel foundry-EAF | 69 | 84 | 90 | 1/76 |
| Steel foundry-EAF oxygen decarb. | 69 | 79 | 81 | 2 |
| Steel foundry-EAF oxygen decarb. | 67 | 76 | 80 | 2 |
| Steel foundry-open hearth | 68 | 86 | 92 | 1/83 |
| Steel foundry-open hearth | 80 | 83 | 85 | 1/233 |
| Steel foundry-open hearth | 82 | 88 | 92 | 1/45 |
| Zinc-fuming furnace | 63 | 75 | 82 | 2 |
| Zinc-retort furnace | 82 | 97 | 99 | 1/44 |
| Zinc-roaster | 99 | 99 | 99 | 1/1 |
| Zinc-smelter-sintering | 92 | 99 | 99 | 1/3 |
| Zinc-vert. retort | 75 | 77 | 86 | 1/43 |

Category: 9
Process: Condensation, Hydration, Absorption, Prilling and Distillation
Material: All

Category 9 includes condensation, hydration, absorption, prilling, and distillation of all materials. These processes involve the physical separation or combination of a wide variety of materials such as sulfuric acid and ammonium nitrate fertilizer. Coke ovens are included since they can be considered a distillation process which separates the volatile matter from coal to produce coke.




| Particle size, µm | Cumulative % less than or equal to stated size (uncontrolled) | Minimum Value | Maximum Value | Standard Deviation |
|---|---|---|---|---|
| 1.0[a] | 60 | | | |
| 2.0[a] | 74 | | | |
| 2.5 | 78 | 59 | 99 | 17 |
| 3.0[a] | 81 | | | |
| 4.0[a] | 85 | | | |
| 5.0[a] | 88 | | | |
| 6.0 | 91 | 61 | 99 | 12 |
| 10.0 | 94 | 71 | 99 | 9 |

[a] Value calculated from data reported at 2.5, 6.0, and 10.0 µm. No statistical parameters are given for the calculated value.

Category: 9
Process: Condensation, Hydration, Absorption, Prilling, Distillation
Material: All

| Source description | Cumulative percent less than or equal to stated size | | | Ref. |
|---|---|---|---|---|
| | 2.5 μm | 6.0 μm | 10.0 μm | |
| Amm. nit. fert.-rotary prilling | 83 | 89 | 96 | 1/336 |
| Amm. nit. fert.-urea prilling | 70 | 89 | 94 | 1/362 |
| Amm. nit. fert.-urea prilling | 73 | 89 | 93 | 1/355 |
| Amm. nit. fert.-urea prilling | 97 | 99 | 99 | 1/48 |
| Amm. nit. fert.-urea prilling | 47 | 61 | 71 | 1/372, 380 |
| Iron & steel prod.-coke oven | 77 | 96 | 98 | 1/142 |
| Pulp mill-sulfate pulp | 77 | 87 | 94 | 1/83-84 |
| Sul. acid-absorb | 59 | 98 | 99 | 3 |
| Sul. acid-absorb. (20% 0) | 97 | 99 | 99 | 3 |
| Sul. acid-absorb. (32% 0) | 99 | 99 | 99 | 3 |

## REFERENCES FOR APPENDIX A


1. Fine Particle Emission Inventory System, U.S. Environmental Protection Agency, Office of Research and Development, Research Triangle Park, NC, 1965.

2. Confidential Test Data from Various Sources, PEI Associates, Inc., Cincinnati, OH, 1985.

3. Final Guideline Document: Control of Sulfuric Acid Production Units, EPA-450/2-77-019, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1977.

4. Air Pollution Emission Test, Bunge Corp., Destrehan, La., EMB-74-GRN-7, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1974.

5. I.W. Kirk, "Air Quality in Saw and Roller Gin Plants", Transactions of the ASAE, Volume 20, No. 5, 1977.

6. Emission Test Report, Lightweight Aggregate Industry, Galite Corp., EMB-80-LWA-6, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1982.

7. Air Pollution Emission Test, Lightweight Aggregate Industry, Texas Industries, Inc., EMB-80-LWA-3, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1981.

8. Air Pollution Emission Test, Empire Mining Company, Palmer, Michigan, EMB-76-IOB-2, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1975.

9. H. Taback, et. al., Fine Particulate Emission from Stationary Sources in the South Coast Air Basin, KVB, Inc., Tustin, CA, 1979.

IO. K. Rosbury, Generalized Particle Size Distributions for Use in Preparing Particle Size Specific Emission Inventories, Contract No. 68-02-3890, PEI Associates, Inc., Golden, CO, 1985.

# APPENDIX B

# CALCULATION SHEET

CALCULATION SHEET

SOURCE IDENTIFICATION

Source name and address: _____

_____

_____

Process description: _____

AP-42 category: _____

Uncontrolled AP-42
emission factor: _____(units)

Activity parameter: _____(units)

Uncontrolled emissions: _____(units)

UNCONTROLLED SIZE DISTRIBUTION

Category name: _____

Category number: _____

| | Particle size, μm | | |
|---|---|---|---|
| | ≤ 2.5 | ≤ 6 | ≤ 10 |
| Generic distribution, Cumulative percent less than or equal to: | | | |
| Mass in size range, (units = tons/year): | | | |

CONTROLLED SIZE DISTRIBUTION

Type of control device: _____

| | Particle size, μm | | |
|---|---|---|---|
| | 0-2.5 | 2.5-6 | 6-10 |
| Collection efficiency Table 4-1: | | | |
| Mass in size range* before control (units=tons/year): | | | |
| Mass in size range after control: | | | |
| Cumulative mass: | | | |

* Note that uncontrolled size data is cumulative percent less than. Control efficiency data applies only to size range and is not cumulative.